AZSPS HDF content details - Introduction

The HDF layout used for the Azimuth Systems scanner processing system (AZSPS) is described below. A restricted subset of all possible HDF interfaces has been used. All data items are only identified and accessed by name. A two level item hierarchy is used; VDatas in single level VGroups. Data items are only stored as single dimension VDatas (with one or more values) or three dimensional scientific data sets (SDS) linked to particular VGroups. Data items can be read using general released HDF utilities or the supplied utility, AZEXHDF. HDF used in this release is HDF3.3r4.

Some items are application related and the user is referred, where relevant, to the appropriate processing program.

Navigation vector items are stored compressed, using a simple multiplier, which is also stored in the HDF file. This saves disc space without loss of precision. Image items are stored as unsigned integers, again scaled to best preserve precision. Optionally image items may be stored as floating point but file sizes will be doubled.

Using unix utilities, HDF files may be copied, moved or archived but NOT viewed, edited, concatenated or truncated.

Data items are described by name, data type, maximum number of occurrences of the type and a brief description. Notes specific to a Vgroup appear after the items description for that VGroup and general notes appear at the end of the document.

VGroup: PROCESSING

Contains details of the file processing level, creation and authorship. Vgroup is created by AZSITE, with PRlevel updated by appropriate programs.

Vgroup name: PRO
Vgroup title: Processing
Data item prefix: PR

Item name	type	maxv	description
PRdesc	C8	64	Vgroup description: Latest processing level of file
PRlevel	C8	8	Latest processing level of file
PRcdate	C8	32	File creation date
PRhostn	C8	64	Host name of creating workstation
PRhostid	C8	16	Host ID of creating workstation
PRsoftware	C8	64	Processing software copyright notice

VGroup: MISSION

Contains all pre-flight, operations and target delimiting values. Site limits may be either or both of time and scan and are inserted by AZSITE. CASI details are inserted by AZCASCHK2 and are obtained from an analysis of the complete CASI data file or files.

Vgroup name: MIS
Vgroup title: Mission
Data item prefix: MI

Item name	type	maxv	description
MIdesc	C8	64	Vgroup description: Mission and site details from flight logs
MIprog1	C8	40	Vgroup 1st processing program name
MIprog2	C8	40	Vgroup 2nd processing program name
MIcopyw	C8	64	Data copyright notice
MIairc	C8	32	Aircraft name
MIpilot	C8	32	Pilot name
MInavig	C8	32	Navigator name
MIoper	C8	32	Operator name
MIbase	C8	32	Sortie base
MIdate	C8	16	Flight date
MIfltno	C8	32	Flight number
MIprojco	C8	64	Project code
MIpiaff	C8	64	Principal investigator and affiliation
MItarget	C8	64	Target name
MIscene	C8	64	Scene identifier from keyword list
MIfline	C8	32	Requestors flight line name/number
MIaspeed	C8	32	Airspeed
MItrack	C8	32	Track
MIalt	C8	32	Altitude
MIweath	C8	128	Weather
MIcloud	C8	32	% of cloud cover
MIland	C8	32	% of land cover
MIcomm	C8	128	Comments
MIfnum	I32	1	CASI field tape file number
MIaper	I32	1	CASI used aperture
MIscanner	C8	8	Scanner name (ATM, AZ16 or CASI)
MIslimit	I32	1	Site limit type flag, 0= none, 1= time, 2= scan, 3= both
MIsday	I32	1	Day number of site start time (1-366)
MIstime	I32	1	Time of site start (HHMMSS)
MIetime	I32	1	Time of site end (HHMMSS)
MIsscan	I32	1	Scan number at site start
MIescan	I32	1	Scan number of site end
MIlimits	C8	128	Lat / Lng from centre of first and last scan

VGroup: NAVIGATION

Contains observed navigation from aircraft survey instruments and base reference station. Up to two sets of independent navigation sets can be saved with position and attitude with each set having independent timing. All times in seconds are consistent and are used to link navigation observations and scans. Navigation data are inserted by one or more of the following programs – AZJPS, AZAHRS, AZIMPORT.

VGroup name:	NAV
Vgroup title:	Navigation
Data item prefix:	NV

Item name	type	maxv	description
NVdesc	C8	64	Vgroup description: GPS/AHRS navigation and scan synchronisation data
NVprog1	C8	40	Vgroup 1st processing program
NVprog2	C8	40	Vgroup 2nd processing program
NVprog3	C8	40	Vgroup 3rd processing program
NVprog4	C8	40	Vgroup 4th processing program
NVprog5	C8	40	Vgroup 5th processing program
NVprog6	C8	40	Vgroup 6th processing program
NVsys1	C8	40	Prime aircraft survey navigation system
NVsys1i	C8	40	Revision number of prime aircraft survey navigation system
NVsys2	C8	40	Secondary aircraft survey navigation system
NVsys2i	C8	40	Revision number of secondary aircraft survey navigation system
NVsys3	C8	40	Inertial aircraft survey navigation system
NVsys3i	C8	40	Revision number of inertial aircraft survey navigation system
NVbase	C8	40	Base reference station navigation system
NVbasei	C8	40	Revision number of base reference station navigation system
NVpos1i	C8	40	Source of position 1 data
NVatt1i	C8	40	Source of attitude 1 data
NVpos2i	C8	40	Source of position 2 data
NVatt2i	C8	40	Source of attitude 2 data
NVspher	I32	1	Spheroid code for aircraft navigation system
NVdatsh	I32	1	Datum shift code for ground navigation system
NVtbase	I32	1	Source of navigation time base
NVdatm	I32	1	Datum code for aircraft navigation system
NVattu	I32	1	Attitude data recorded code
NVacor	f64	1	Vector of aircraft nav posn to scanner offset
NVut2gt	f64	1	Time correction used to convert NMEA UTC times to GPS time in seconds
NVtimec	I32	1	Time data code: 0= GMT
NVjday	I32	1	Year day for site start
NVstime	I32	1	Time of site start (HHMMSS)
NVetime	I32	1	Time of site end (HHMMSS)
NVtime	sI32	var	Time of position set 1 observations (GPS dec secs)
NVlat	sI32	var	Latitude (dec degs)
NVlng	sI32	var	Longitude (dec degs)
NVhgt	sI32	var	Spheroid height (metres)
NVqual	sI32	var	Position 1 data quality flag
NVasecs	sI32	var	Time of GPS attitude set 1 observations (dec secs)
NVroll	sI32	var	Aircraft GPS roll (positive right wing down) (dec degs)
NVpitch	sI32	var	Aircraft GPS pitch (positive nose up) (dec degs)
NVhead	sI32	var	Aircraft GPS heading (0-360 clockwise from true north) (dec degs)
NVaqual	sI32	var	GPS Attitude 1 data quality flag
NVtime2	sI32	var	Time of position set 2 observations (GPS dec secs)
NVlat2	sI32	var	Latitude (dec degs)
NVlng2	sI32	var	Longitude (dec degs)
NVhgt2	sI32	var	Spheroid height (metres)
NVqual2	sI32	var	Position 2 data quality flag
NVasecs2	sI32	var	Time of AHRS attitude set 2 observations (dec secs)
NVroll2	sI32	var	Aircraft AHRS roll (dec degs)
NVpitch2	sI32	var	Aircraft AHRS pitch (dec degs)
NVhead2	sI32	var	Aircraft AHRS heading (dec degs)
NVroll2r	sI32	var	Aircraft AHRS roll rate of change (dec degs)
NVpitch2r	sI32	var	Aircraft AHRS pitch rate of change (dec degs)
NVhead2r	sI32	var	Aircraft AHRS heading rate of change (dec degs)
NVasync	sI32	var	AHRS synchronisation quality flag
NVagsecs	sI32	var	
NVagsync	sI32	var	
NVsctcor	F64	1	Time correction from nav observation to scan observation
NVscnum	sI32	var	Scan number
NVscsecs	sI32	var	Scan synchronisation time (GPS dec secs)
NVtime_sc	F64	1	Scale multiplier for time
NVasecs_sc	F64	1	Scale multiplier for attitude time
NVlat_sc	F64	1	Scale multiplier for latitude
NVlng_sc	F64	1	Scale multiplier for longitude
NVhgt_sc	F64	1	Scale multiplier for height
NVroll_sc	F64	1	Scale multiplier for roll
NVpitch_sc	F64	1	Scale multiplier for pitch
NVhead_sc	F64	1	Scale multiplier for head
NVagsecs_sc	F64	1	
NVagsync_sc	F64	1	
NVscnum_sc	F64	1	Scale multiplier for scan number
NVscsecs_sc	F64	1	Scale multiplier for scan sync time

Notes:

1: Navigation vectors are stored as scaled integers (format sI32); file values are to be multiplied by the appropriate scale to obtain a double precision floating value.
2: Spheroid and datum codes are documented in AZGCORR User Manual pages.

VGroup: SCAN COORDINATES

Contains post processed and interpolated navigation on a per scan basis.

VGroup name: SCO
Vgroup title: Scan coordinates
Data item prefix: CO

Item name	type	maxv	description
COdesc	C8	64	Vgroup description: Navigation data interpolated to scan times
COprog1	C8	40	Vgroup 1st processing program
COprog2	C8	40	Vgroup 2nd processing program
COoffs	I32	1	Offset code for scanner in aircraft
COstime	I32	1	Time of site start (dec secs)
COetime	I32	1	Time of site end (dec secs)
COsscan	I32	1	Scan number of site start
COescan	I32	1	Scan number of site end
COscans	I32	1	Total scans with navigation
COscint	I32	1	Interval of scan number for scans with navigation
COtime	sI32	var	Time (GPS dec secs)
COlat	sI32	var	Latitude (dec degs)
COlng	sI32	var	Longitude (dec degs)
COhgt	sI32	var	Spheroid height (metres)
COroll	sI32	var	Roll (dec degs)
COpitch	sI32	var	Pitch (dec degs)
COhead	sI32	var	Heading (dec degs)
COqual	UI32	var	Interpolation quality bitwise OR'd flag, 0= interp/extrap, 1= posn, 2= attitude
COtime_sc	F64	1	Scale multiplier for time
COlat_sc	F64	1	Scale multiplier for latitude
COlng_sc	F64	1	Scale multiplier for longitude
COhgt_sc	F64	1	Scale multiplier for height
COroll_sc	F64	1	Scale multiplier for roll
COpitch_sc	F64	1	Scale multiplier for pitch
COhead_sc	F64	1	Scale multiplier for heading

VGroup: MAPPING DETAILS

Contains mapping parameters used for final image correction in AZGCORR.

Vgroup name: MAP
Vgroup title: Mapping details
Data item prefix: MP

Item name	type	maxv	description
MPdesc	C8	64	Vgroup description: Mapping parameters for level 3
MPprog1	C8	40	Vgroup 1st processing program
MPsphc	I32	1	Spheroid code for map projection
MPdatm	I32	1	Datum shift code from navigation to mapping datum
MPproj	I32	1	Map projection code
MPlng0	F64	1	Longitude of origin
MPlat1	F64	1	Latitude of origin or 1st parallel
MPlat2	F64	1	2nd parallel
MPglat	F64	1	Latitude of grid origin
MPglng	F64	1	Longitude of grid origin
MPgx0	F64	1	Grid coordinate at grid origin
MPgy0	F64	1	Grid coordinate at grid origin
MPscf	F64	1	Project scale factor at projection origin
MPdshc	I32	1	Datum shift code, acquisition to mapping datums
MPdsVG	C8	16	Datum shift name
MPdsvec	F64	7	Datum shift vector for single point transformations
MPimx0	F64	1	Image origin grid x
MPimy0	F64	1	Image origin grid y
MPtiles	I32	1	number of tiles in image
MPcxy	F64	var	tile coordinates

VGroup: LEVEL 2

Contains details of user application, level 2, processing.

Vgroup name: LV2
Vgroup title: Level2
Data itemprefix: L2

Item name	type	maxv	description
L2desc	C8	64	Vgroup description: Level 2 user processed data
L2prog1	C8	40	Vgroup 1st processing program
L2prog2	C8	40	Vgroup 2nd processing program
L2para1	C8	128	User program parameter list1
L2para2	C8	128	User program parameter list2

VGroup: ATM / AZ16

Contains ATM scanner recording parameters and recorded, calibrated or geometrically corrected image data stored as 16 bit integer to level 1b and either 16 bit integer or 32 bit floating for level 2 and level 3.
Level 1 data is inserted by AZATM. Data recorded with the DEI320 has 12 channels and from the AZ16 11 channels.

Vgroup name: ATM
Vgroup title: ATM
Data item prefix: AT

Item name	type	maxv	description
ATdesc	C8	64	Vgroup description: ATM scanner details, calibration and data
ATprog1	C8	40	Vgroup 1st processing program
ATprog2	C8	40	Vgroup 2nd processing program
ATprog3	C8	40	Vgroup 3rd processing program
ATprog4	C8	40	Vgroup 4th processing program
ATsbend	I32	1	Sbend correction applied in scanner flag 0= no, 1= yes (Note 1)
ATrgyro	I32	1	Roll gyro correction applied in scanner flag, 0= no, 1= yes (Note 1)
ATrmedia	C8	16	Aircraft data recording media
AThddt	C8	16	HDDT tape external label name (Note 1)
ATcct	C8	64	CCT tape external label name (Note 1)
ATtype	C8	8	Daedalus ATM type eg: 1268 or AZ16
ATid	C8	32	ATM ID owner (i.e. NERC)
ATfov	F32	1	Field of view (dec degs)
ATpixfov	F32	1	Pixel field of view (mradians)
ATpixrec	I32	1	Pixels per scan recorded
ATpixred	I32	1	Pixels per scan reduction method, 0= none, 1=average, 2= nearest
ATpixsav	I32	1	Pixels per scan saved
ATsscan	I32	1	Target start scan
ATescan	I32	1	Target end scan
ATchan	I32	1	Channels/bands recorded
ATbpix	I32	1	Bits per pixels recorded
ATgains	F32	var	Channel gains (ATM only)
ATwavu	F32	var	Channel upper wavelength limit
ATwavl	F32	var	Channel lower wavelength limit
ATscps	F32	1	Nominal scans per second recorded
ATbbtf	I32	1	Black body temperature saved type flag, 0= fixed for file, 1= table
ATbb1	F32	var	Set black body 1 temperature
ATbb2	F32	var	Set black body 2 temperature
ATbbscan	I32	var	scan at which temp applies for table option
ATsbb1	F32	var	Recorded blackbody 1 temperatures
ATsbb2	F32	var	Recorded blackbody 2 temperatures
ATvbb1	F32	var	Average sensor response to blackbody 1 temperatures
ATvbb2	F32	var	Average sensor response to blackbody 2 temperatures
ATsync	F32	var	Synchronisation flag
ATcal	C8	32	Calibration version
ATcalfmt	C8	32	Calibration format
ATcalfile	C8	32	Calibration file name
ATcaltab	F32	100	Calibration values table (100 for ATM, 20 for AZ16)
ATradsc	F32	var	Channel radiance scaling multiplier
ATrunits	C8	32	Radiance units
ATimgmin	F32	var	Channels minimum values (excluding zero)
ATimgmax	F32	var	Channels maximum values (excluding overflows)
ATimgzer	I32	var	Channels no. of zero values
ATimgovr	I32	var	Channels no. of overflowed values
SCimtype	I32	1	Image type flag, 0= as source, 1= resampled
SCorder	I32	1	Pixel order flag, 0= l to r, 1= r to l in direction of lines increasing
SClndir	I32	1	Scan line direction flag, 0= flight direction, 1= north up
SCtiles	I32	1	Tiles in image, 0= not tiled single image, >0 = number of tiles
SCbands	I32	1	Bands in image
SCpixels	I32	1	Pixels in image
SClines	I32	1	Lines in image
SCpixfmt	I32	1	Pixel format flag, 0= 8bit unsigned, 1= 16bit unsigned
SCHDFfmt	I32	1	Pixel HDF number format flag, see HDF documentation for details
SCimover	F32	1	flag value indicating overflowed values, see general note 2
SCimunder	F32	1	flag value indicating underflowed or missing values, see gen note 2
SCpixbytes	I32	1	Bytes per pixel
SCposn	I32	1	Position data relation flag, 0= posns per scan, 1= posns per image

SCaxes	I32	1	Coordinate axes for position flag, 0= along flt dir, 1= N up
SCxypix	I32	1	Relation of coordinates to pixel flag, 0= centre, 1= BL
SCpixwid	F32	1	Pixel width - x or scan direction (metres)
SCpixhgt	F32	1	Pixel height - y or flight direction (metres)
SCviewty	I32	1	Image view type flag, see general note 4
SCvplane	I32	1	Image view (y) plane position (metres)
SCposimag	F64	var	Image position coordinates for SCposn=1, see general note 5
SCposscan	I32	1	Position info per scan content flag
SCsused	I32	var	Scans used in level 3 image (field scan numbers)
SCbused	I32	var	Bands used in level 3 image (level 1 band numbers)
SCpxyn	I32	1	No. of pixels per side of tile
SCpxy_sc	F64	1	Image xy scale multiplier
ATimgxy	I32	var	Image tiles coordinate list
ATdata	SDS	3 x var	Image data

ATM notes:

1: Items sbend, rgyro, hddt and cct are specific to the original ATM system

VGroup: CASI

Contains CASI scanner recording parameters and recorded, calibrated or geometrically corrected image data stored as 16 bit integer to level 1b and either 16 bit integer or 32 bit floating for level 2 and level 3. Up to three sets of image data may occur: Image, SRC and ILS, see ITRES CASI documentation.

Contains
Vgroup name: CAS
Vgroup title: CASI
Data item prefix: CA

Item name	type	maxv	description
CAdesc	C8	64	Vgroup description: CASI scanner details and data
CAprog1	C8	40	Vgroup 1st processing program
CAprog2	C8	40	Vgroup 2nd processing program
CAprog3	C8	40	Vgroup 3rd processing program
CAprog4	C8	40	Vgroup 4th processing program
CAserial	I32	1	*CASI scanner serial number
CAswver	C8	32	*CASI scanner software version number
CAexa	C8	64	Exabyte tape external label name
CAfnum	I32	1	Field tape file number
CAconfig	C8	32	Scanner configuration file name
CAsday	I32	1	Target start day of year
CAstime	I32	1	Target start time (HHMMSS)
CAmode	I32	1	*CASI operating mode flag, 0= spatial, 1= spectral, 2= full frame
CAg	F64	4	*G coefficients
CAinteg	F32	1	*CCD integration period (msecs)
CAapert	F32	1	*CASI file header reported aperture
CAfapert	F32	1	Aperture appearing in majority of none dark frame headers
CAoaxis	F32	1	Pixel of CCD optical axis
CAfov	F32	1	Total field of view (dec degs)
CApside	I32	1	CCD port side flag,
CAsscan	I32	1	Site start scan
CAescan	I32	1	Site end scan
CAlooks	I32	1	*Number of looks in spectral image
CAlooksp	I32	1	*Look spacing in spectral image
CAlookc	I32	1	*Centre look pixel in spectral image
CAsumdch	I32	1	*Number of channels per band summed in enhanced spectral
CAsrcpres	I32	1	SRC image present flag, 0= no, 1= yes
CAsrcbands	I32	1	SRC no. of bands
CAsrcchan	I32	1	band used for src
CAsrcpix	I32	1	SRC no. pixels
CAilspres	I32	1	ILS present flag, 0= no, 1= yes
CAilsbands	I32	1	ILS no. of bands
CAilspix	I32	1	ILS no. of pixels
CAbstart	I32	var	*band start of image data
CAbend	I32	var	*band end of image data
CAwavc	F32	var	*wavelength centre
CAwavh	F32	var	*wavelength half bandwidth
CAcalfile	C8	32	Calibration file name
CAradsc	F32	1	Radiance scaling multiplier
CArunits	C8	32	Radiance units
CAiunits	C8	32	ILS irradiance units
CAimgmin	F32	var	Image bands minimum, excluding zeros
CAimgmax	F32	var	Image bands maximum, excluding overflows
Caimgzer	I32	var	Image bands zeros
CAimgovr	I32	var	Image bands overflows
CAsrcmin	F32	var	SRC band minimum, excluding zeros
CAsrcmax	F32	var	SRC band maximum, excluding overflows
CAsrczer	I32	var	SRC band zeros
CAsrcovr	I32	var	SRC band overflows
CAilsmin	F32	var	ILS bands minimum, excluding zeros
CAilsmax	F32	var	IILS bands maximum, excluding overflows
CAilszer	I32	var	ILS bands zeros
CAilsovr	I32	var	ILS bands overflows

SCimtype	I32	1	Image type flag, 0= as source, 1= resampled
SCorder	I32	1	Pixel order flag, 0= l to r, 1= r to l in direction of lines increasing
SCIndir	I32	1	Scan line direction flag, 0= flight direction, 1= north up
SCtiles	I32	1	Tiles in image, 0= not tiled single image, >0 = number of tiles
SCbands	I32	1	Bands in image
SCpixels	I32	1	Pixels in image
SClines	I32	1	Lines in image
SCpixfmt	I32	1	Pixel format flag, 0= 8bit unsigned, 1= 16bit unsigned
SCHDFfmt	I32	1	Pixel HDF number format flag, see HDF documentation for details
SCimover	F32	1	Flag value indicating overflowed values, see general note 2
SCimunder	F32	1	Flag value indicating underflowed or missing values, see gen note 2
SCpixbytes	I32	1	Bytes per pixel
SCposn	I32	1	Position data relation flag, 0= posns per scan, 1= posns per image
SCaxes	I32	1	Coordinate axes for position flag, 0= along flt dir, 1= N up
SCxypix	I32	1	Relation of coordinates to pixel flag, 0= centre, 1= BL
SCpixwid	F32	1	Pixel width - x or scan direction (metres)
SCpixhgt	F32	1	Pixel height - y or flight direction (metres)
SCviewty	I32	1	Image view type flag, see general note 4
SCvplane	I32	1	Image view (y) plane position (metres)
SCposimag	F64	var	Image position coordinates for SCposn=1, see general note 5
SCposscan	I32	1	Position info per scan content flag
SCsused	I32	var	Scans used in level 3 image (field scan numbers)
SCbused	I32	var	Bands used in level 3 image (level 1 band numbers)
SCpxyn	I32	1	No. of pixels per side of tile
SCpxy_sc	F64	1	Image xy scale multiplier
CAimgxy	sI32	var	Image xy coordinates
CAsrcxy	sI32	var	SRC xy coordinates
CAilsxy	sI32	var	ILS xy coordinates
CAimage	SDS	3 x var	Image data, spectral or spatial bands
CAsrc	SDS	3 x var	SRC data, scene recovery for spectral mode
CAils	SDS	3 x var	ILS data

CASI notes

1: Descriptions starting with * indicate values transferred without alteration from the CASI data file. Full details can be found in CASI documentation.

General Notes

1: Data types:

C8	CHAR8	8 bit characters, used for text strings which are zero terminated
I32	INT32	32 bit signed integers
sI32	INT32	32 bit integers containing scaled floating point values
UI32	UINT32	32 bit unsigned integer
F32	FLOAT32	32 bit floating point
F64	FLOAT64	64 bit floating point
SDS	see below	format indicated by SCHDFfmt, may be UINT16 or FLOAT32

Item dimensions marked as variable (var) or SDS may be of any length.
Variable and SDS items only appear in VGroups if they have 1 or more values.

2: Image items

Image items are either direct instrument recorded data or values derived from these. Allowance is made for values overflowed, underflowed or missing. The following strategy has been adopted and must be followed in level 2 processing to remain compatible with level 3 programs.

a) UINT16 image items have two special values:
    0xffff (65536) indicates an overflowed value
    zero indicates underflowed or missing data
b) FLOAT32 image items have two similar special values; to allow for flexibility for level 2 processing these values are stored in ATM and CAS Vgroup items, SCimover and SCimunder. The following rule must be adhered to to avoid image data loss: valid image items must be between SCimover and SCimunder; images values >= SCimover and <= SCimunder will be omitted from level 3 calculations.

Note that these items are valid for UINT16 and FLOAT32 image data.

Default values are:	UINT16	SCimover 65536.0	SCimunder 0.0
Default values are:	FLOAT32	SCimover 1.0e^30	SCimunder -1.0e^30

3: Tiled images

Image tiling is indicated by SCtiles > 0. Image is tiled into side by side squares (by no. of pixels). Image data for tiles are stored in the image data items ATdata, CAimage (spatial mode), CAsrc. Note that CAimage (spectral mode) and CAils are not tiled and always stored in one piece. The key to the position of tiles is stored in the appropriate VG***xy item after scaling. Image data for squares may be in any order from the total image area; the key may be ordered for best access or other reasons.
a) SCpxyn, SCpxy_sc, ATimgxy, CAimgxy, CAsrcxy and CAilsxy are only used if the image is tiled.
b) In none tiled files, image items are stored as bands, lines and pixels. Typically Level 1 and 2 data is none tiled and Level 3 may be either.

4: Derived image views

Images resulting from level 3 processing are projected to a surface different from the aquisition surface, the selected surface is indicated by the SCviewty flag with values:
0= as source, ie image is as original and not resampled
1= mean sea level of local datum
2= to a plane parallel with the mapping spheroid (fixed GPS flight height)
3= to observed flight height + correction
4= digital elevation model (DEM) in local datum
5= DEM + Geoid/Spheroid correction (navigation to mapping spheroids)

5: Image Coordinates

The position of a resampled and corrected image is defined by a set of coordinate values and increments:
With origin at pix[0], line[0] and using map projection grid coordinates; SCposnimag values are:
[0] = x origin, [1]= y origin, [2]= xinc per pixel, [3]= yinc per pixel, [4]= xinc per line, [5]= yinc per line

Program: **AZEXHDF**

Purpose: Extract, list or reformat selected data from AZSPS HDF files

Use: At unix prompt type: azexhdf filename [options]

Usage information: (obtained by executing program with no command line parameters)

azexhdf	[[][-h][-S][-B][-BS]] hdf [options...]
-h hdf	: hdf input file (-h optional)
-h vg	: VGroup list; hg ommitted lists all VGroups
	: vg = vg name or item id, e.g. Coordinates or CO
-h vd	: vd = single VData name to list
-SIBIBS	: output to do; omitted gives summary listing
-S fn	: convert image data to Sunraster file
-B fn	: convert image data to BIL binary file
-BS fn	: convert image data to BSEQ binary file, fn = output filename
-Bv	: verbose detail listing for conversion
-Bs	: output stats file as fn.stats
-Bh c	: output histogram to stats file for all data selected, c= no. of columns 0= 256
-Cx fn	: create binary file (fn) with CASI spectral and ILS coordinates,
	: pixels are 0=pixels; lines 0-lines xy's are grid coords in pairs,
	: format is tenths of metres in signed lonmg
-Cr fn	: as for Cx but coords are col, row pairs to match SRC image, format is uint16
	: NB: options –C? must be run separately from BIL creation;
	: -p may be used; line order as for image convention, see -l
-d dn	: image data item name if not default, default is read from file for ATM and CASI
-c r g b	: band nos for colour image Sunraster file
-m c	: band no for monochrome image Sunraster file
-p p0 pn l0 ln	: image patch limits, pixels and lines for Sunraster, BIL and image item listings
-ph	: Does image listing in hex
-pbseq	: If present does image listing in BSEQ order
	: if not present (default) image list in BIL order
-po	: only image listing done
-r	: output DN values as radiance using default scaler
-rm m	: m = multiplier for DN scaling, for BIL output
-bl b0 b1 ... -1	: list of bands for BIL file
-br b0 bn	: band range, bands b0 to bn
-l	: line order reversed on output to files, defaults
	: HDF levels 1 and 2 : scan 0 first
	: HDF leve 3 : northern most scan first
-v max	: max items to list for vectors in summary listing, def: 1
-vf fn	: filename for complete vector output
-vs	: add scab number in col 0 of multiplexed output
-vn item	: HDF vector data item name to list in full on vector output file,
	: repeat use for several items
	: NB: this is for none SDS items only - for SDS items use summary listing
	: with -p and -d values
-vp n0 n1 . . –1	: list of decimal places required for a set of multiplexed vectors;
	: if only n0 is given this will apply to all items; defaults dps are: v < 90 : 5 else 5
	: except ??lat? and ??lng? are 7 dps
-vm	: ALL requested vectors to be output multiplexed, NB: vectors must be from

	: the same Vgroup and of equal length, eg: pitch roll and heading
-vi st en	: limiting indices of vectors, default is all values

Notes:

1: Filenames can be complete paths.
2: VGroup and data item names are case sensitive.
3: Band numbers are 1 relative.
4: Pixel and line patch limits are zero relative.

Details of run options:

1: HDF file contents listing

typing: **azexhdf -h hdf_file_path** at the unix prompt

Will obtain a summary listing to stdout. Parameters **-hg** and **-hd** with appropriate VGroup and data item names can be used to restrict the listing to one VGroup or just 1 data item.

By default vector items listings are limited to 5 items at the start of the vector and the last one, if there are more than 5 values. To list more of the values use option **-v** to get the required number from the start of the vector or **-vi** to get a selected part from the middle.

eg: azexhdf t1.hdf Will give a summary listing of all items on t1.hdf

eg: azexhdf t1.hdf -hg NV -hd NVlat -v 100

Will get a listing of the first 100 and last values of the NAV VGroup vector containing aircraft latitudes.

For image items stored as SDS listing are obtained by using the options: **-bl** to select one or more bands and **-p** to define a pixel patch. By default the item listed will be ATdata for ATM VGroup and CAimage for CASI VGroup; other items can be selected using option: **-d**

2: Mulitplexed vectors

Selected vectors can be listed or output to an ascii file multiplexed. This is only valid if the items are related and exactly match in length and gaps. A typical use of this is to get navigation items or scan sync items. **-vf** gives an output file; **-vm** selects multiplexed mode; and repeated use of **-vn** gives the required items. Note: this is for non-SDS items only.

eg: azexhdf t1.hdf -vf nav.dat -vm -vn NVtime -vn NVlat -vn NVlng -vn NVhgt

Will obtain a 4 column file with all entries of GPS time, latitude, longitude and height.

3: HDF file reformatted to BIL or BSEQ

Image items are extracted and reformatted to BIL or BSEQ files with the options **-BIL or -BSEQ** to select the file format, along with an appropriate file path to contain the output.
The following optional parameters can be used to modify the output: **-d** to select a non-default item (ATM is ATdata, CAS is CAimage); **-bl** to select one or more bands; **-p** to limit pixels and lines; **-Bs** to get a summary statistics file and **-Bh** to get a histogram for each selected band. **-Bv** will obtain extra coordinate details for level 3 files.

BIL and BSEQ output files data entries are in the same format as level 1 files, ie binary unsigned integers. Pixels are output with file indexed zero first and lines, with line indexed zero first. Bands are output in the order requested by parameter **-bl**, eg: -bl 5 3 2 -1 would give these three bands in order 1, 2, 3 on the output file; if the file was BIL the sequence would be:

line 0 band 5 pixels 0 to n
line 0 band 3 pixels 0 to n
line 0 band 2 pixels 0 to n
line 1 band 5 .... etc

Line and pixel order imply that a level 1 file will be in flight direction down the file, with pixel zero on the right. By default, a level 3, north up file will be going north down the file, with pixel zero to the west; directions can be changed in level 3 processing.

Note that for input to the AZSPS utility dimp, the options **-Bs** and **-Bh** must be used; dimp requires these to get details of the image for display purposes. For use in dimp, the parameter **-rm** allows scaling of the BIL values to brighten an otherwise dark image as a default display.

4: Sun raster output

A SunRaster format file can be created from 1 or 3 selected bands to give an image viewable using utilities such as imagetool or XV. Note that if the selected image is beyond a certain size or contains too may colour levels these utilities will resample and remap the pixels.

Option **-S** selects the output format and provides the output file; **-c** or **-m** provides the band from the HDF file and selects RGB colour or monochrome output file format.; **-p** can be used to restrict the image patch.

eg: azexhdf t1.hdf -S a.sunr -c 5 3 2

Will obtain a SunRaster RGB file for bands 5 for red, 3 for green and 2 for blue of the whole default image item on t1.hdf.

Limitations and error messages

AZEXHDF may not work correctly and may well crash if the input hdf file was created by a previous program run that terminated with an hdf error. This is one of many deficiencies in the HDF system which is unable to detect corrupted or improperly closed files.

AZEXHDF will correctly report if an input file is missing or not an HDF file. It will then terminate.

Program: **AZGCORR**

Purpose: **Scanner image data geometric correction**

Introduction:

AZGCORR combines scanner image data and post processed navigation recorded or interpolated at each scan and interpolates a map projection referenced rectilinear output image corrected for aircraft position, attitude and ground surface separation computed from aircraft spheroid height, digital elevation data and geoid-spheroid separation estimates.

Special processing is available for non-image data (e.g.: CASI spectral and ILS); corrected pixel coordinates are saved to allow positioning of pixels either on a map or scene image.

Inputs to AZGCORR are run time parameters from the command line, Level 1B HDF, Level 2 HDF or a combined Level 1B HDF and related BIL/BSEQ image file. Outputs are a brief run listing and a Level 3A (default with or without DEM) or 3B HDF (with use of field GPS observation of GCPs) file.

Navigation and image data input to AZGCORR must have been processed using the correct programs in the Azimuth Systems package to ensure that all data items are present and as expected. The one exception is Level 2 data, the basis of which is image data extracted from a Level 1B file with AZEXHDF; massaged by a user program and input to AZGCORR still in BIL or BSEQ format along with its originating Level 1B HDF file.

AZGCORR does all image processing in rectilinear coordinates, therefore the first step is to convert the navigation from geographic coordinates on GPS satellite datum to a suitable survey map projection. It is important to note that all appropriate data items (DEM, etc) must be on the same datum and projection. This is discussed below.

A summary of command line options and parameters can be obtained by running AZGCORR –help with no parameters; this output will be the most up to date version and will supercede details in this document if the two version dates are not the same.

Details and typical use of the various options are described below.

1: Notes on Correction Concepts

1.1 Goals for correction

Stated simply the purpose of the program is to produce an output image which overlays an existing map. The rotating mirror (ATM) or pushbroom (CASI) scans have positions calculated for every pixel and then the image is interpolated to a rectilinear grid, which may be projected to a plane relative to the aircraft or related to existing topographic data.

It is important to note that this ground referencing is only achieved by using observed scanner (aircraft) position and attitude and referencing scan positioning to elevation (DEMs) information. Ground control points are ONLY used for 'calibrating' DEMs and geoid-spheroid separation data.

1.2 Navigation - relation to Datums and Spheroids

All navigation on the earth's surface is referenced to a set of axes and a model which describes the static and dynamic geometry of the earth and navigation platform; this is a geodetic datum. For the sake of this discussion we can ignore all parameters except earth geometry and time. For the sake of brevity a datum is given a name or even a mnemonic; throughout the world there are several hundred different datums. Current GPS datum is called WGS84 (World Geodetic System agreed in 1984).

To make position observation and calculations tractable the shape of the earth is represented by the nearest simple geometric figure consistent with the desired accuracy. For survey use sufficient accuracy is obtained with a the earth represented by an ellipse rotated about the earth's north south (spin) axis. This 3D figure is called a spheroid (or ellipsoid by some texts).

Of course this simplified figure only approximates the actual earth surface, the geoid, at any point. To relate the two figures a local origin is chosen with measured lateral position and assigned vertical position (height). All heights for a locality are then relative to this reference point. In UK the point is at Newlyn, Cornwall and the height zero is related to mean sea-level. A locality height (topographic) map in grid form is also known as a digital elevation model.

It is important to note that before the days of GPS heights and positions on maps were obtained separately. Heights where by bubble or optical levelling and thus relate to the local gravity normal. Positions where obtained by angular triangulation or optical or microwave trilateration. Both sets of observations have varying errors which are minimised (not removed) by network adjustment. A network of observed points, both position and height can then be 'filled-in' on the ground with more levelling or other techniques or used to scale a series of stereographic aerial photographs from which height and position details can be measured using a stereogrammetric plotter. In general height are an order of magnitude less accurate than positions.

On the other hand, GPS surveying observes both position and height simultaneously, in fact the observation is the 3D axis position of the observation site relative to the centre of the satellite orbit (earth centre). With appropriate equipment and techniques it is possible to make this 3D observation to a few millimetres. More importantly each GPS site is essentially independent from other observations, errors being related mainly to satellite constellation geometry. This allows static site and vehicle positions to be independently observed but retain a very high degree of relative accuracy.

As can be expected there is a problem relating positions obtained from GPS observations and those from traditional geodetic surveying. There is no simple transformation to solve this to any degree of accuracy beyond a few metres; at best a fudge is possible (like the recommended OS procedure for GPS to National Grid). For purely economic reasons the correct solution for a whole country will never be performed, ie. re-observe all original ground points by GPS and recompile all maps.

The relationship between a simple spheroid and its geoid is obtained by a combination of satellite orbit observation, satellite height above sea level measurement, and details of the Earth's local observed gravity. Merging and adjusting this lot using spherical harmonics produces a geoid-spheroid separation map for the spheroid in question. The appropriate sum of the spheroid height, geoid-spheroid separation value and the geoid (DEM) height allows the height of, for example an aircraft, above a DEM to be obtained only using GPS observations to 5 metres or so.

The highest accuracy can only be achieved by GPS ground control points used to calibrate stereo photographs from which new DEMs are obtained. Or by means of the latest laser topographic scanners, positioned by GPS.

To summarise for our use of GPS for remote sensing aircraft surveying:

a) all modern surveying and platform positioning is by GPS which gives a 3D position for an observation.
b) relating dynamic platform observations to static field observation using GPS is easy to a few tens of centimetres.
c) relating these observations to existing maps requires various adjustments, the first of which is the transformation of the aircraft position on the GPS datum to the local mapping datum; moderate accuracy (few metres) is done using an observed data fudge.
d) higher accuracy requires field GPS observations of control points

The default method used in AZGCORR, to transform from GPS satellite datum (WGS84) to UK National Grid, uses the Ordnance Survey recommended 'National Grid/ETRF89 Transformation Parameters 2/1995 ver 1.2' claimed to be accurate to the 2 metre level.

Our scan positions are now in UK National Grid coordinates.

1.3 Map projections

The default procedure for UK outlined above does a one step conversion from WGS lat/long/height to UK national Grid map projection coordinates. The more usual method of transformation does this in two steps allowing more flexibility.

First the GPS position (latitude, longitude and spheroid height) on satellite datum (WGS84) is transformed to a local datum (lat, long, height). Then the geographic (spheroidal) coordinates are transformed to a suitable rectilinear coordinate set using a map projection. Representing points on a spheroid by points on a flat surface, is at best, a compromise. For survey use only a few map projections have the required characteristics of accuracy and scale and direction representation, these are:

a) Transverse Mercator (eg: UTM, UK National Grid etc)
b) Lambert Conical Orthomorphic
c) Universal Polar Stereographic (above 80 degs north or south)

Each of these projections has a set of defining parameters usually agreed on a national scale. GCORR allows the selection of these projections and parameters; details are described below.

1.4 Digital Elevation data

From the above discussions on datums and map projections it should be clear that elevation data is a measure of heights above some datum on a given spheroid, and without transformation or other massaging can only be used in the context of this spheroid. If the data is also positioned in map projection grid coordinates it is even more closely linked. Consequently care must be taken that selected datum shifts, map projection and DEM data are all self-consistent.

Elevation data may be input to the program as AZGCORR internal format grids (see below), NTF contour or grid files or a flat file. NTF files must comply with the appropriate OS format description for layout and content. AZGCORR saves or creates a grid from these files, to cover the image area requiring correction. Previously gridded data may not be altered in grid spacing. NTF contour files are converted internally using a user requested grid interval to form the required grid. The requested grid interval must be chosen to be equal to or greater than the output pixel spacing. If too small an interval is used the program run time will increase considerably, the program may run out of memory and no improvement in image correction will be achieved; two times the pixel spacing is more than adequate.

In the case where the DEM does not completely cover the image grid, the missing parts are filled with default or user supplied fill values before the geoid-spheroid correction is made. In the case of completely offshore sites where geoid-spheroid correction is required, the program will create a zero filled grid and apply the correction; ignore the 'no data' message.

1.4 Time

Time only becomes important when the Level 2 options to calculate pixel view and solar illumination angles are used. Except for these solar calculations for which UTC is required, GPS time of day is used throughout for identifying and merging data. Full details of time will be available with the integrated release of level 2 processing in azgcorr.

1.5 Image Interpolation

In the current release three image interpolation options are provided: a) bi-cubic, b) bi-linear and c) nearest neighbour. The first two methods will produce pixel values not in the input image, method c) will not generate extra values and must be used for classified images. In all cases image data is only used if it has DN values between the upper and lower limits stored in SCimover and SCimunder respectively.

User control is also provided for defining the size of gaps that will be interpolated (or filled - nearest neighbour) and the minimum number of pixels considered to be a good 'run'. Both these parameters have limited importance as they only affect the edge of images where the pixel distortion makes the data of little value and generally can be left to default. Care must be taken when a small pixel size is used together with large aircraft motion; in this case the gap parameter may need to be increased to 6, 8 or even 10 to avoid gaps at the image edge.

The nature of the sampling process in both line scan (ATM) and CCD (CASI) scanners results in the DN value obtained for a pixel being a measure of the reflection source by up to two pixels from the centre of a given pixel and controlled by the pixel response function (sort of Gaussian). When interpolating observed scan data to get a rectilinear output no interpolation method is any more 'accurate' than another; just different and all only an approximation to the value that would be obtained if the output pixel was measured directly.

With this in mind, it is suggested that any 'scientific' operation eg. atmospheric correction, is performed on the Level 1 data and geometric correction applied to this Level 2 product. Any 'none scientific' operation eg classification, is performed on the bicubic interpolated geometric corrected image where pixels are in their correct geometric relation with each other.

1.6 CASI correction

CASI data requires some extra processing options to cater for the three possible data components recorded in the different operating modes of the instrument: image data, spectral data and ILS.

Briefly the data types consist of:

rec. mode	item	content
SPATIAL:	image:	several bands of continuous pixels
	ILS:	same number of bands of single pixels
SPECTRAL	image:	many bands of spaced out pixels
	SRC	single band continuous pixel image for scene positioning
	ILS:	same number of bands as image for single pixel
ENHANCED SPECTRAL	image:	many bands of continuous pixels but of restricted image width
	SRC	single band continuous pixel image for scene positioning
	ILS:	same number of bands as image for single pixel

Using the appropriate options AZGCORR processes these items as follows:

spatial image, spectral SRC, enhanced spectral SRC and enhanced spectral image: handled as ATM ie continuous image, all three methods of interpolation may be used and a rectilinear interpolated image results.

spectral image, enhanced spectral image and ILS: geometrically corrected grid coordinates are calculated for each pixel and saved on the HDF file to allow positioning over the SRC image. Note that the data items will also be copied to the level 3 file. Coordinates are saved in vectors CAimgxy for image pixels and CAilsxy for the ILS pixel. Note that ONLY selected lines and bands are transferred to the level 3 file.

spectral image: a special option (-cspi) allows spectral data to be processed as though it is a continuous (touching pixels), space between pixels is filled by the selected interpolation method.

Note that interpolation option has no affect on the pixel coordinates calculated for non-image items.

1.7 Viewing the results

Interpolated image items can be converted to BIL or BSEQ files by the AZEXHDF utility and input into any standard image processing package. Coordinates output as listing during the AZGCORR run can be used to relate the images to maps.

CASI non-image items: spectral, enhanced spectral and ILS can be obtained on BIL or BSEQ format files and their related coordinates on separate files for use in user programs.

The unsupported utility DIMP can be used to directly view image items all levels of the hdf files used by the processing package. This enables viewing of the unaltered pixels in 8 or 24 bit colour (graphics controller permitting), no dithering, re-interpolation or pixel value re-mapping is applied. The program also provides a combined display of CASI SRC with overlaid spectral and with interactive access to view spectra at mouse selected pixels. Other displays are possible for Level 1 and 2 data, see DIMP usage for options.

1.8 Practical aspects of running the program

With the amount of data and calculation required, correction of all bands for even a moderate sized site can take several hours on a Sparc workstation; the following details will help to avoid wasted time.

AZGCORR run times will be **extended** by:

a) increased number of bands
b) increased number of scan lines
c) reduced pixel size,
d) presence of DEM
e) presence of other programs running on the CPU
f) limited amount of usable memory
g) shortage of disc space for output file

AZGCORR may run out of memory with an inappropriate combination of:

a) too small pixel size, and...
b) diagonal flight line, and...
c) too many input scan lines

The main points to note when running AZGCORR is its potentially long run time. Users are advised, until they obtain a feel for these times, to restrict the number of bands selected for correction and to use an output pixel size no smaller than 5 metres. Run times are several times longer if a DEM is present; typical times for ATM are 20 minutes per 1000 scans per band on a Sparc 5.

The program allocates dynamically many large buffers depending on the direction of the data and the output pixel size. Memory is inversely related to the pixel size. The program will halt with an error message if too little memory is available. The program gives the total size of buffers allocated in the summary listing.

It is important to note on a Sparc workstation that the amount of usable memory (assuming a user has no installation restrictions) is about twice the actual RAM provided the disc swap partition is large enough for all tasks trying to run concurrently.

2: Options and Parameters

Notes:

a) Letters preceded by minus signs are the parameter names as summarised in the Usage listing.
b) Filenames always implies full unix paths.
c) Command line parameters and values may be in any order.
d) Latitude and longitude values in signed decimal degrees are -ve for south and west.
e) All units of distance are in metres.
f) Option requirements in typical runs are optional unless stated.

option: **-1 fn** **level 1 HDF file path**

fn = input Level 1 HDF file path

requirement: **MANDATORY** default: NONE

option: **-3 fn** **level 3 HDF file path**

fn = output Level 3 HDF file

requirement: **MANDATORY** default: NONE

option: **-B l b t s o f** **BIL or BSEQ file content details**

l = total lines on file
b = total bands on file
t = number type on file, 0= uint16, 1= float32
s = scale
o = offset to convert B file values for geometric correction and saving as uint16, v = p * s + o
f = fill value for bad pixels; good pixels are < f
if f = 0 the default values of 0 and 0xffff (uint16) or 10e30 (float32) are assumed

requirement: MUST be used if -Bi or -Bs are used
defaults: l, b NONE; s = 1.0; o = 0.0

option: **-Bi fn** **BIL file path**

fn = BIL input file

Default: none

option: **-Bs fn** **BSEQ file path**

fn = BSEQ input file

Default: none

d... Geodetic datum shift details

option: **-dN** **No datum shift performed**

No datum shift is performed, data remains in WGS84 throughout processing.

option: **-d95** **OS 1995 datum shift method applied**

Ordnance Survey 95 method using GRS80 datum. See Ordnance Survey publication:
National Grid/ETRF89 Transformation Parameters. Geodetic Information Paper No. 2. 2/95 V1.2

This is the default if no -d option is used.

option: **-dDUTCH** **Netherlands National Grid datum shift**

Use WGS84 <-> RD (Bessel) for Netherlands National Grid

-d7... Single point 7 para method

option: **-d7 sp dx dy dz rx ry rz sc 7 parameter Bursa-Wolff shift**

Applies a 7 parameter Bursa-Wolff single point transformation

sp =spheroid code
spheroid code 0=International Hayford 1950, 1= Airy 1830 (UKNG)
3= WGS84, etc.
dx,y,z = origin shift in metres
rx,y,z = axis rotations in secs
sc = scale excess in ppm, ie scale = 1+sc/1000000 eg: -8.3

option: **-d7 a p2 dx dy dz rx ry rz sc** **7 parameter Bursa-Wolff shift**

Applies a 7 parameter Bursa-Wolff single point transformation

a = semi-major axis (m) eg: 6378388.0 OR...
spheroid code 0=International Hayford 1950, 1= Airy 1830 (UKNG)
3= WGS84, etc.
p2 = semi-minor axis or reciprocal flattening or eccentricity (metres)
eg: 6356911.9 or 297.0 or 1.0012345 OR ...
spheroid code ie. 0, 1, 3 etc. if spheroid code has been given for a
dx,y,z = origin shift in metres
rx,y,z = axis rotations in secs
sc = scale excess in ppm, ie scale = 1+sc/1000000 eg: -8.3

NB: a and p2 must be the same used for the map projection

See UKOOA publication 1991 and Geodesy by Bomford.

There are no defaults except as mentioned.

-m... Map projection details

option: **-mUKNG** **TM set to UK National Grid.**

This is the default if no -m is used.

option: **-mIRNG** **TM set to Irish National Grid**

option: **-mUTM cm** **UTM with central meridian**

TM set to UTM with supplied central meridian (longitude) = cm (signed decimal degrees)

option: **-mUTM zo** **UTM with UTM zone**

TM set to UTM with supplied UTM zone number

option: **-mTM s1 s2 lao lno sc nor eor** **Comprehensive TM**

Transverse Mercator with user supplied parameters.

s1 = spheroid code or semi-major axis (a) 0= INT, 1= Airy, 3= WGS84
s2 = semi-minor (b) or reciprocal flattening (f) or eccentricity (e^2)
lao = projection origin latitude
lno = central meridian (longitude) (cm)
sc = scale factor at cm
nor, eor= grid coords at origin and cm

No defaults are provided.

option: **-mTMS**

Forces use of southern hemisphere for TM

option: **-mLAM s1 s2 h lao lno eor nor la1 la2** **Lambert Conical**

Lambert Conical Orthomorphic with one or two parallels.

s1, s2, lao, lno, eor nor as TM above

h = hemisphere n/N=north, s/S=south
la1, la2 = two standard parallels (lats), if la1=la2 single parallel projection used

option: **-mOM do s1 s2 sc xor yor lac la1 ln1 la2 ln2** **Oblique Mercator**

when do =0 for centre and 2 points on centre line

option: **-mOM do s1 s2 sc xor yor lac lnc azc** **Oblique Mercator**

when do=1 for centre and azimuth of centre line

s1 = spheroid code or semimajor axis (a)
0=INT, 1=Airy, 3=WGS84 etc.
s2 = semiminor axis (b), recip.flat. (f) or eccen (e^2)
or 0 if spheroid code has been given
sc = scale factor at centre of projection
xor, yor = grid coords at origin
lac = lat at centre
lnc = long at centre
la1, ln1 = first point on centre line
la2, ln2 = second point on centre line

azc = azimuth (east of north) of centre line

option: **-mRSO** **Rectified Skew Orthomorphic**

parameters as for Oblique Mercator

option: **-mNZ** **New Zealand projection**

no parameters required

option: **-mDUTCH** **Netherlands National Grid projection**

no parameters required

Netherlands National Grid (Rijksdriehoeksmeting –RD) projection on Bessel 1841 spehroid.

a... Corrected image alignment relative to map

option: **-an** **North up**

Default if -a.. is not used

option: **-af** **Rectangle centred on flight line**

option: **-a az** az = user clockwise angle from grid N

option: **-pab** **Output pixel coordinate alignment**

If this option is present pixel coordinate limits are aligned at bottom left (SW) corner. If this option is not present coordinate limits are aligned at the centre of pixels.
NB1: aligning at bottom left implies final image limits are to the outside edge of the peripheral pixels
NB2: CASI spectral, enhanced spectral and ILS coords are always returned pixel centred

option: **-r rv** **Coordinate rounding**

rv = coordinate rounding value, def: is pixel size rounding is to multiples of rv

option: **-ro xm ym xx yx** **Enforced output limits**

Output image enforced x,y limits (grid coords): allows different data sets to be matched
: ** NB: wrong values may extend the image and cause runtime memory problems and large file size

h... Aircraft height control

option: **-h ht** **Constant height**

ht = aircraft height above ground

option: **-hn** **Navigation height used**

Selects the use of GPS navigation height. This is the default if no -h is used.

option: **-hs sc** **Navigation height with correction**

Same as -hn but allows a user constant height correction to be made.

sc = height correction to be added to aircraft hgt

Requirement: options -hn or -hs MUST be used with DEM and geoid-spheroid correction.

option: **-hsu** **Height correction for WGS84**

Height correction for WGS84 geoid-spheroid applied for map centre from UK coverage grid or sphsep file

option: **-p dx dy** **Output pixel size**

Output pixel x, y sizes in metres.

Default: none
Requirement: **MANDATORY**

option: **-l st en** **Input scan lines to process**

Scan line numbers to limit processing, must be within the range of items CAsscan, CAescan (CASI vgroup) or ATsscan, ATescan (ATM vgroup).

Default: with -l, missing is to process all scans on the input file.

b... Input bands to process

option: **-b a..-1** **List of input bands to process.**
option: **-br b1 bn** **Inclusive band range to process**

Note that if less than the total bands are processed output bands may be reordered. For example:
with -b 5 3 2 -1
the output image bands will be 1 = input band 5, 2 = input band 3 etc

Default with no -b option is to process all input bands.

option: **-be** **Bad band / line correction**

Enables the use of bad band / line flags in SCbedit array to eliminate bands or lines from the output interpolation

c... CASI processing options

option: -call process all present data in default modes
option: -cspa DO NOT process IMG if spatial, def: process
option: -cils process ILS, def: do not process
option: -csrc process SRC, def: do not process
option: -cspe process spectral, def: do not process
option: -cspi process spectral as complete image

Default for ILS and spectral is to save pixel coords as extra bands and apply no image interpolation

option: **-cc o p fv** **CASI ccd and lens details**

CASI ccd/lens details to replace program defaults...

o = optic axis (nadir) pixel n or n.5, ie: 230 or 225.5 but not 124.3
p = port pixel 0= pixel 1 is on the port side, 1= max pixel is on the port side
fv = lens field of view in decimal degrees

option: **-ccd o p fv pfv tp** **CASI general ccd and lens details**

CASI general ccd/lens details to replace program defaults...

o = optic axis (nadir) pixel n or n.5, ie: 230 or 225.5 but not 124.3
p = port pixel 0= pixel 1 is on the port side, 1= max pixel is on the port side
fv = lens field of view in decimal degrees
pfv = field of view port pixel to optic axis
tp = total pixels in field of view

i... Output image interpolation control

option: **-ic sm** **Bi-cubic**

Method uses a bicubic tensioned spline, sm is the spline tension.
This is the default if –i is not used.

sm = smoothing value (0.001-100.0) def= 1.0, 0.001 is very smooth, 100 is linear interp

option: **-in** **Nearest neighbour**
NB: suggested use with class maps only

option: **-il** **Bilinear**

option: **-il2** second pass interp is linear
option: **-in2** second pass interp is nearest neighbour
option: **-ic2 sm** second pass interp is bicubic, sm = smoothing

option: **-it g** thinning option on second pass interpolation

g = multiple of pixel spacing, default = 0.5, pixels are omitted if closer together than g

option: **-g gm gr** **Image gap control**

gm = gap size in multiples of pixel size, ie gap (metres) = gm * pix_size
gr = good data run, which will be interpolated

These controls only affect the edge of the image as gaps rarely occur elsewhere. In general the defaults should be used.

Defaults: gm = 4, gr = 4

e... Digital Elevation Model (DEM) control

option: **-e fn** **Digital Elevation file**

fn = DEM file path, may be repeated: 8 times, file(s) may be NTF contour OR grid OR internal grid format ** **but not mixed**

option: **-eg gr** **DEM grid increment**

For use with NTF contour files, defines the saved DEM grid increment, should be >= 2* pix inc.

Default: 10 metres

option: **-ef** **DEM force slow search for ground intersection**

This option is occasionally needed in areas of rapid topographic change (steep slopes).

option: **-ez v** **DEM fill grid edge**

v = value to fill empty grid edge nodes
Default: fill with nearby values

option: **ed or c r xm ym xx yx gi** **flat file ascii DEM definition**

This defines the contents of a flat file containing DEM values. Files may have no header, in which case -e fn gives the filename or a header may be used to avoid using this -ed option, in this case use -eh to give the file name.

or = data order, =0 rows(x) S->N, =1 rows N->S
c = cols
r = rows
xm, ym = SW corner coords;
xx, yx = NE corner coords
gi = grid increment

grid values on file must be separated by space(s) and may have decimal points
NB: only ONE file may be present

option: **-eh fn** **flat file with header**

fn = DEM file path, for flat file with a header

header is the -ed items separated by spaces... eg: 0 512 1024 0 0 511 1023 1.0

option: **-es fn**

fn = geoid-spheroid separation grid file path
if fn = NO, no geoid-spheroid correction will be applied

Default if -es is not present is to use program built in g-s values which cover UK:
SW: 49.75 N 7.5 W to NE: 60.75 N 2.75 E
Sites outside this range must use a g-s file

n Navigation control

-nr : force use of nav roll values, default: CASI always used, ATM: only if no roll gyro
-nrr : use roll values reversed in sign
-nrp : use pitch and roll values reversed in sign
-ns : reverse scan direction
-no n : n= no. of records to offset nav from scans
-na p r h : attitude correction values to be added

v Listing content

-v : verbose listing mode

3: Examples of run parameters

Basic run, no DEM

```
azgcorr -1 fnin.hdf -3 fnout.hdf -p 5 5
```

Basic run, DEM present

```
azgcorr -1 fnin.hdf -3 fnout.hdf -p 5 5 -e fndem.ntf
```

DEM run with line and band selection

```
azgcorr -l 1900 2900 -b 2 4 7 -1 fnin.hdf -3 fnout.hdf -p 5 5 -e fndem.ntf
```

DEM, nearest neighbour interpolation and CASI spatial run processing image and ILS items

```
azgcorr -in -cils -1 fnin.hdf -3 fnout.hdf -p 5 5 -e fndem.ntf
```

Basic run with input from ATM data in floating point on a BIL level 2 file

```
azgcorr -Bi fnlev2.bil -B 1200 12 1 1 0 0 -1 fnin.hdf -3 fnout.hdf -p 5 5
```

Usage information: obtained by executing program: azgcorr -help

azgcorr -- ver: 4.0.2 Feb 27 2000 (C) Azimuth Systems UK 1996,1999

Usage: azgcorr -1 fn -3 fn [options...]

geometric correction of ATM and CASI scanner image data

```
-1 fn            : fn= input Level 1 HDF file **Mandatory
-3 fn            : fn= output Level 3 HDF file **Mandatory

-Blbtsof         : details for image input from BIL or BSEQ file
                 : l = total lines on file, b = total bands, t = number type, 0= uint16, 1= float32
                 : s, o = scale and offset to convert B file values for geom correction and saving as uint16, v = p * s + o
                 : f = fill value for bad pixels; good pixels are < f
                 :  if f = 0 the default values of 0 and 0xffff (uint16) or 10e30 (float32) are assumed
-Bi fn           : fn= BIL input file
-Bs fn           : fn= BSEQ input file

-d...            : Geodetic datum shift details for tranforms from WGS84
                 : to the selected map projection datum. Note that datum
                 : values depend on the country and target map projection
                 : and except for the published ones below are not provided internally
                 : in azgcorr
                 : NB: datum shift and projection must be consistent for
                 : the final image to be correctly positioned
-dN              : NO dsh performed data is in WGS84 throughout
-d95             : Ord Surv 95 method using GRS80 datum, def if no -d
-dDUTCH          : use of WGS84 <-> RD (Bessel) for Netherlands Nat Grid

-d7...           : single point 7 para method - see UGuide
-d7 sp dx dy dz rx ry rz sc
                 : where sp=spheroid code 0= Int (Hayford 1950, 1= Airy 1830 (UKNG);
                 : 3= WGS84, etc. see UGuide for others
-d7 a p2 dx dy dz rx ry rz sc
                 : where a = semi-major axis (m) eg: 6378388.0 or...
                 : spheroid code 0= Int (Hayford 1950, 1= Airy 1830 (UKNG); else see UGuide for others
                 : p2 = b or reciprocal flattening or eccentricity
                 :          eg: 6356911.9 or 297.0 or 1.0012345 or...
                 : 0 if spheroid code has been given
                 : dx,y,z = origin shift in metres
                 : rx,y,z = axes rotation in decimal secs
                 : sc = is scale change in ppm minus 1 eg: -8.3
                 : NB: a and p2 must be the same used for the map projection

-m...            : map projection details...
-mUKNG           : TM set to UK National Grid, default if no -m
-mIRNG           : TM set to Irish National Grid
-mUTM cm         : TM set to UTM with central meridan = cm
-mTM s1 s2 lao lno sc nor eor : Transverse Mercator
                 : s1 = spheroid code or semimajor axis (a)
                 : 0= INT, 1= Airy, 3= WGS84 etc (see user guide)
                 : s2 = semiminor (b), recip flat. (f) or eccen (e^2),
                 : lao= lat origin; lno= central meridian (cm)
                 : sc= scale factor at cm,
                 : nor, eor= grid coords at origin and cm
-mTMS            : forces use of southern hemisphere for TM
-mLAM s1 s2 h lao lno eor nor la1 la2 : Lambert Conical Ortho
                 : s1, s2, lao, lno, eor nor as TM, h= hemisphere n/N=north, s/S=south
                 : la1, la2= two standard parallels (lats), if la1=la2 single parallel projection used
                 : NB: for more projections and details see Uguide
-mOM ...         : Oblique Mercator
-mOM do s1 s2 sc xor yor lac la1 ln1 la1 la2     (if do = 0)
-mOM do s1 s2 sc xor yor lac lnc azc             (if do = 1)
                 : do = defining option...
                 : do=0 for centre and 2 points on centre line
                 : do=1 for centre and azimuth of centre line
                 : s1 = spheroid code or semi-major axis (a)
                 :        0= INT, 1= Airy, 3= WGS84 etc (see Uguide)
                 : s2= semi-minor (b), recip. flat. (f) or eccen. (e^2)
                 :        or 0 if spheroid code has been given
                 : sc= scale factor at centre of projection
                 : xor, yor= grid coords at origin
                 : lac= lat. at the centre
                 : lnc= long. at the centre
                 : la1, ln1= first point on centre line
                 : la2, ln2= second point on centre line
                 : azc= azimuth (east of north) of centre line
-mRSO ...        : Rectified Skew Orthomorphic
```

	: parameters as for the Oblique Mercator
-mNZ . . .	: New Zealand projection (no parameters)
	: NB: for more projections and details see Uguide
-mDUTCH	: Netherlands National Grid (Rijksdriehoeksmeting – RD)
	: projection on Bessel 1841 spheroid (no parameters)
-a[nlfl az]	: corrected image alignment an= north up = default
	: af= rectangle centred on flight line, az= user clockwise angle from grid N
-pab	: align pixel coordinates at bottom left (SW) comer, default: coordinates at centre of pixel
	: NB: align at bottom left implies final image limits are to the outside edge of the peripheral pixels
	: NB: CASI spectral, enhanced spectral and ILS coords are always returned pixel centred
-r rv	: rv= coordinate rounding value, def: is pixel size rounding is to multiples of rv
-ro xm ym xx yx	: output image enforced x,y limits (grid coords): allows different data sets to be matched
	: ** NB: wrong values may extend the image and cause runtime memory problems and large file size
-h...	: Aircraft height correction options
-h ht	: ht = aircraft height above ground
-hn	: use nav height: default
-hs sc	: sc= height correction to be added to aircraft hgt
-hsu	: height correction for WGS84 geoid-spheroid
	: applied for map centre from UK coverage grid or file sphsep
-p...	: pixel details...
-p dx dy	: output pixel size in x and y ** Mandatory
-l st en	: line (count) to process def= all input file
-b...	: bands required to be processed to output file
-b a..-1	: HDF output band list (def = all on input file)
-br b1 bn	: inclusive range of bands from b1 to bn
	: default: if -b not present all bands are processed
-be	: enable use of SCbedit to remove bad bands
-c...	: CASI processing options...
-call	: process all present data in default modes
-cspa	: DO NOT process IMG if spatial, def: process
-cils	: process ILS, def: do not process
-csrc	: process SRC, def: do not process
-cspe	: process spectral, def: do not process
-cspi	: process spectral as complete image
	: default for ILS and spectral is to save pixel coords as extra bands and apply no image interpolation
-cc o p fv	: CASI ccd/lens details to replace file defaults...
	: o= optic axis (nadir) pixel n or n.5,
	: p= port pixel 0= pixel 1, 1= max pixel,
	: fv= lens field of view in degrees
-ccd o p fv pfv tp	: general ccd details to replace file defaults
	: o= optic axis (nadir) pixel n or n.5,
	: p= port pixel 0= pixel 1, 1= max pixel,
	: fv= lens field of view in degrees
	: pfv = total field of view port pixel to optic axis
	: tp = total pixels in field of view
-i...	: output image interpolation method, def= bicubic
-ic sm	: bi-cubic (method equivalent to cubic convolution)
	: sm= smoothing value (0.001-100.0) def= 1.0, 0.001 is very smooth, 100 is linear interp
-in	: in= nearest neighbour
-il	: il= bilinear
-il2	: second pass interp is linear
-in2	: second pass interp is nearest neighbour
-ic2 sm	: second pass interp is bicubic, sm = smoothing
-it g	: thinning option on second pass interpolation
	: g= multiple of pixel spacing, default = 0.5
	: pixels are omitted if closer together than g
-g...	: image gaps and good data check controls during interpolation
-g gm gr	: a gap > pix_size * gm and good data run > gr, def: 4 4
-e...	: Digital Elevation Model use, def no DEM
	: ** NB: DEM grids are assumed to be on the datum and in the coordinate system defined by the selected
	: datum shift and map projection
-e fn	: fn+ DEM file path, may be repeated: 8 times, file(s) may be NTF or internal grid format ** but not mixed
-eg gr	: DEM grid increment, should be >= 2* pix inc, def= 10
-eg gm	: DEM grid margin multiplier, margin = grinc * mult, def= 5
-ef	: DEM force slow search for ground intersection
-ez v	: DEM fill grid edge empty nodes with value= v, default: fill with nearby values
-ed or c r xm ym xx yx gi	: flat file ascii DEM definition
	: or = data order, =0 rows(x) S->N, =1 rows N->S; c= cols, r = rows, xm, ym = SW corner coords;
	: xx, yx = NE corner coords; gi = grid increment; grid values on file must be separated by space(s)
	: NB: only ONE file may be present
-eh fn	: fn= DEM file path, for flat file with a header; header is the -ed items separated by spaces...
	: eg: 0 512 1024 0 0 511 1023 1.0

-es fn	: fn= geoid-spheroid separation grid file path
-es NO	: NO geoid-spheroid correction will be applied, default: use built in g-s values which cover UK:
	: SW: 49.75 N 7.5 W to NE: 60.75 N 2.75 E sites outside this range must use a g-s file
-v	: verbose listing mode